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Evolution of fuel plate parameters during deformation in rolling

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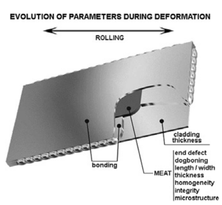
HIGHLIGHTS

- Evolution of defects when manufacturing dispersion fuel plates.
- Aspects of dispersion fuel plates fabrication.
- What happen during the manufacturing of dispersion fuel plates?
- Clarifying the deformation of fuel plates by rolling.

GRAPHICAL ABSTRACT



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ABSTRACT

The Nuclear and Energy Research Institute – IPEN/CNEN-SP routinely produces the nuclear fuel necessary for operating its research reactor, IEA-R1. This fuel consists of fuel plates containing U_3Si_2-Al composites as the meat, which are fabricated by rolling. The rolling process currently deployed was developed based on information obtained from literature, which was used as a premise for defining the current manufacturing procedures, according to a methodology with an essentially empirical character. Despite the current rolling process being perfectly stable and highly reproducible, it is not well characterized and is therefore not fully known. The objective of this work is to characterize the rolling process for producing dispersion fuel plates. Results regarding the evolution of the main parameters of technological interest, after each rolling pass, are presented. Some defects that originated along the fuel plate deformation during the rolling process were characterized and discussed. The fabrication procedures for manufacturing the fuel plates are also presented.

1. Introduction

Research reactors are used primarily for producing radioisotopes and materials testing. The IEA-R1 research reactor of IPEN-CNEN/SP is used for primary radioisotopes production, mainly ^{131}I. The fuel element for the IEA-R1 reactor is formed by assembling a series of spaced fuel plates, allowing the passage of a water flow that serves as coolant and moderator. The fuel element is composed of 18 flat and parallel fuel plates.

Since 1988, IPEN has been manufacturing fuel for the IEA-R1 reactor. The picture-frame technique is used [1,2]. The fuel currently produced adopts the U_3Si_2-Al dispersion with uranium concentration of 3.0 gU/cm^3 [3]. The rolling procedures currently implemented have been developed based on literature information [4–6], which were used as premises for defining the current manufacturing procedures, according to an essentially empirical methodology. For this reason, even though the current rolling process is perfectly stable and highly reproductive, it is not well characterized and is therefore not fully understood.

The knowledge of the rolling process adopted for fabricating fuel plates is important to understand and to correct possible deviations that might occur in the manufacturing process. Furthermore, a deeper understanding of this process allows for adjusting it

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quickly to new specifications, in the case of manufacturing fuels for use in other research reactors. This is especially important since a new research reactor is planned to be built in Brazil [7–9] and IPEN will have the incumbency of providing the fuel for the new reactor research.

The objective of this work is to characterize the rolling process currently adopted by IPEN, specifically regarding the evolution of dimensional parameters of the fuel plate as a function of its deformation in the rolling process. The parameters studied were length, width and thickness of the fuel meat, thickness of the cladding, dog-boning evolution, bonding evolution, and microstructure of the meat.

2. Experimental

2.1. Description of fuel plate manufacturing

The method for manufacturing fuel plates by a hot and cold rolling sequence is well-developed, and has been extensively used for the production of fuel elements for many research reactors around the world. The fuel element is an assembled set of fuel plates. It consists of regularly spaced parallel plates forming a fuel assembly. The fuel plates have a meat containing the fissile material, which is entirely cladded with aluminum. They are manufactured by adopting the traditional assembling technique of a fuel meat (or "briquette") inserted in an aluminum frame and cladded by aluminum plates, which are bonded with subsequent rolling.

Powder metallurgy techniques are used in the manufacture of the briquette, which uses U_3Si_2 as the uranium fissile composite. The briquette is made with powdered fissile material and pure aluminum powder, which is the structural matrix material of the briquette. Fig. 1 presents scanning electron micrographs showing the typical appearance of U_3Si_2 (A) and aluminum (B) particles. After rolling, the briquette composes the meat of the fuel plate, which is perfectly isolated from the external environment, protected by the aluminum cladding. The briquette is a rectangular parallelepiped with rounded corners. The powders for each individual briquette are separately weighed and combined for blending. For pressing the briquettes, a pressing pressure of about 5 ton/cm^2 is used.

The picture-frame technique [1,2] is used to produce the fuel plates, where the briquettes are processed with mechanical working. An assembly is used, which consists of a frame, the fuel meat (briquette) and two cover plates, as illustrated in Fig. 2. The assembly is converted into plates to provide the required dimensions and complete sealing of the fuel. The frame provides both lateral support and material for the cladding. The briquette and frame are bonded to the covers by hot bonding during a hot-rolling processing. The material used as frame and covers is 6061 aluminum.

The final dimensions specified for the fuel plates are 625 mm long by 71 mm wide by 1.52 mm thick. The dimensions of the fuel meat are 600 mm long by 65 mm wide by 0.76 mm thick. The thickness of the frame plate is 4.2 mm and the thickness of the cover plates is 2.5 mm. The width and length of the frame and cover

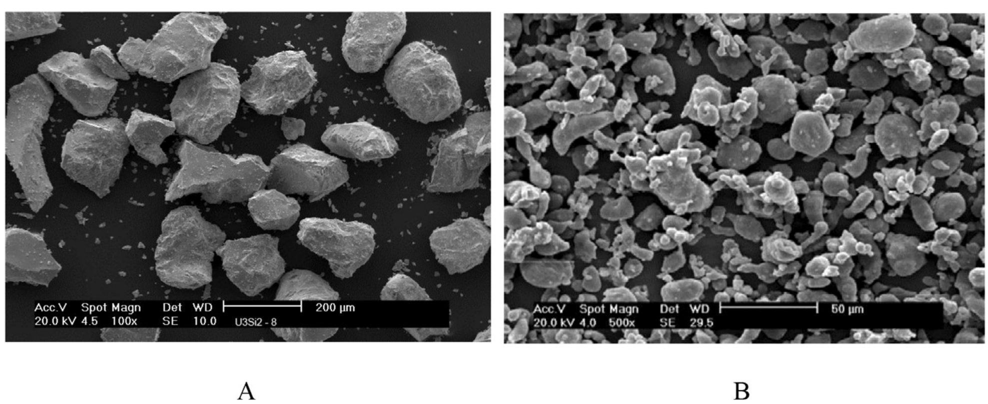

Fig. 1. Typical morphology of U_3Si_2 (A) and Al (B) powders (secondary electrons).

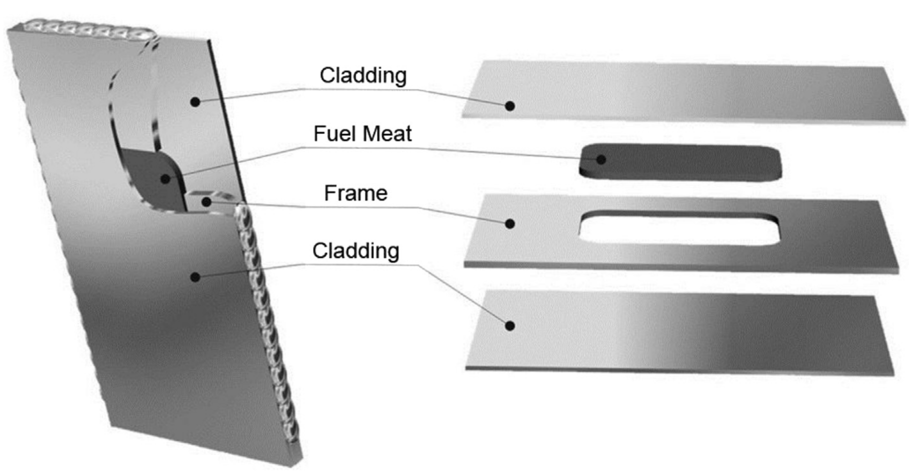

Fig. 2. Diagram illustrating the assembling of the set meat-frame-covers.